CHM11$_3$ General Chemistry I (Dr. Jen) Key

Chapter 19 Review

1) (a) Write the formation reaction for $AgNO_3$ (s)

Substance	$\Delta G_f°$ (kJ/mol)	$\Delta H_f°$ (kJ/mol)
$AgNO_3$ (s)	-33.4	-124.4
$AgNO_3$ (aq)	-34.2	-101.7

(b) Predict whether the entropy of the system will increase of decrease upon its formation.

(c) Determine the entropy change. Is it consistent with your prediction?

(d) Is dissolving $AgNO_3$ in water and endothermic or exothermic process?

(e) Calculate the entropy change when $AgNO_3$ is dissolved in water.

(see attached for work)

2) What is the standard entropy change of the reaction below at 298 K with each compound at the standard pressure? **N_2 (g) + 3 H_2 (g) → 2 NH_3 (g)**

(a) -198.2 J/K (b) 76.32 J/K (c) 303.2 J/K (d) -129.7 J/K (e) 384.7 J/K

(see attached for work)

3) The entropy will usually increase when

I. a molecule is broken into two or more smaller molecules. ✓
II. a reaction occurs that results in an increase in the number of moles of gas. ✓
III. a solid changes to a liquid. ✓
IV. a liquid changes to a gas. ✓

(a) I only (b) II only (c) III only (d) IV only (e) I, II, III, and IV

4) Calculate $\Delta G°$ for the reaction given the following information:

2 SO_2 (g) + O_2 (g) → 2 SO_3 (g)

$\Delta G_f°$ for SO_2 (g) = –300.4 kJ/mol $\Delta G_f°$ for SO_3 (g) = –370.4 kJ/mol

* Note: You can also practice using $\Delta H_f°$ & $S°$ values to double check your work *

(a) -70.0 kJ (b) +70.0 kJ (c) -670.8 kJ (d) -140.0 kJ (e) +140.0 kJ

5) For the following reaction at 25 °C, $\Delta H° = +115$ kJ and $\Delta S° = +125$ J/K. Calculate $\Delta G°$ for the reaction at 25 °C.

SBr_4 (g) → S (g) + 2 Br_2 (*l*)

(a) +152 kJ (b) -56.7 kJ (c) +77.8 kJ (d) +37.1 kJ (e) -86.2 kJ

6) The heat of vaporization of freon, CCl_2F_2, is 17.2 kJ/mol at 25 °C. What is the change of entropy for one mole of liquid freon when it vaporizes at 25 °C? (Hint: The vaporization process is at equilibrium and what is true for ΔG at equilibrium?)

(a) 57.7 J/K (b) 0.688 J/K (c) 5.13×10^3 kJ/K (d) 3.16 J/K (e) 239 J/K

7) Estimate the boiling point of $Br_2(l)$ ($\Delta H = 30.9$ kJ; $\Delta S = 93.0$ J/K). $Br_2(l) \rightarrow Br_2(g)$

(a) 85 °C (b) 373 °C (c) 177 °C (d) 59 °C (e) 44 °C

8) For the reaction, A + B → C, $\Delta H^\circ = +30$ kJ; $\Delta S^\circ = +50$ J/K. Therefore the reaction is:

(a) spontaneous at all temperatures.
(b) nonspontaneous at all temperatures.
(c) spontaneous at temperatures less than 600 K.
(d) spontaneous at temperatures greater than 600 K.
(e) spontaneous only at 25°C.

9) Which statement is **incorrect**?

(a) At constant pressure, $\Delta H = \Delta E + P\Delta V$
(b) The thermodynamic symbol for entropy is S.
(c) Gibbs free energy is a state function.
(d) For an endothermic process, ΔH is negative. ← should be positive
(e) If the work done by the system is greater than the heat absorbed by the system, ΔE is negative.

$\Delta E = q + w$ so rearranging gives you $\Delta H = -P\Delta V$ (throwback/review from Chap. 5)

$\Delta E = q + w$ (−) (+)

Table of Selected Thermodynamic Data at 298 K

	ΔG_f° (kJ/mol)	ΔH_f° (kJ/mol)	S° (J/mol·K)
P (g)	280.0	316.4	163.2
S_8 (g)	49.7	102.3	430.9
H_2 (g)			130.58
O_2 (g)			205.0
NH_3(g)	-16.66	-46.19	192.5
SO_2 (g)	-300.4	-296.9	248.5
SO_3 (g)	-370.4	-395.2	256.2
Br_2 (l)			152.3
Br_2 (g)	3.14	30.71	245.3
Cl_2 (g)			222.96
N_2 (g)			191.50

CHM113 General Chemistry I (Dr. Jen)

1)

Substance	$\Delta G_f°$ (kJ/mol)	$\Delta H_f°$ (kJ/mol)
$AgNO_3$ (s)	-33.4	-124.4
$AgNO_3$ (aq)	-34.2	-101.7

(a) Write the formation reaction for $AgNO_3$ (s)

$Ag^+_{(aq)} + NO_{3(aq)} \rightleftharpoons AgNO_3(s)$

$AgNO_3(aq)$

• aq is in liq. H_2O → (s)

↓ disorder/entropy

(b) Predict whether the entropy of the system will increase of decrease upon its formation.

(c) Determine the entropy change. Is it consistent with your prediction?

$\Delta G° = \Delta H° - T\Delta S°$ ← want 298K b/c std cond'ns

↑ determine from $\Delta G_f°$ ↑ determine from $\Delta H_f°$

rewrite → $\Delta S° = \frac{\Delta G° - \Delta H°}{-T}$

$= \frac{(.8\,kJ) - (-22.7\,kJ)}{-(298K)}$

$= -7.89 \times 10^{-2}\,kJ/K \times \frac{1000}{1kJ}$

$\Delta S° = -78.9\,J/K$

$\Delta G° = [1\,\Delta G_f°\,AgNO_3(s)] - [1\,\Delta G_f°\,AgNO_3(aq)]$

$= [1\,mol \times \frac{-33.4\,kJ}{mol}] - [1\,mol \times \frac{-34.2\,kJ}{mol}]$

$\Delta G° = +.8\,kJ$

$\Delta H° = [1\,mol \times \frac{-124.4\,kJ}{mol}] - [1\,mol \times \frac{-101.7\,kJ}{mol}] = -22.7\,kJ$

(d) Is dissolving $AgNO_3$ in water and endothermic or exothermic process?

$\Delta H°_{forward\ (aq)\rightarrow(s)} = -22.7\,kJ$ ← $\Delta H°$ values

$\Delta H°_{reverse\ (s)\rightarrow(aq)} = +22.7\,kJ$ → positive ∴ endothermic

↑ equal in magnitude; opposite in sign

(e) Calculate the entropy change when $AgNO_3$ is dissolved in water.

$\Delta S°_{forward} = -78.9\,J/K$

$\Delta S°_{reverse} = +78.9\,J/K$

2) Know $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ (reactants → pdt) Want ΔS°_{rxn}

$\Delta S^\circ_{rxn} = \sum n S^\circ(\text{products}) - \sum m S^\circ(\text{reactants})$

$= [2 S^\circ_{NH_3}] - [(1 S^\circ_{N_2}) + (3 S^\circ_{H_2})]$

$= \left[2\,\text{mol} \times \frac{192.5\,J}{\text{mol}\cdot K}\right] - \left[\left(1\,\text{mol} \times \frac{191.50\,J}{\text{mol}\cdot K}\right) + \left(3\,\text{mol} \times \frac{130.58\,J}{\text{mol}\cdot K}\right)\right]$

$= [385.0\,J/K] - [583.44\,J/K]$

$\Delta S^\circ_{rxn} = -198.2$ (a)

4) Know $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ Want ΔG°

$\Delta G_f^\circ = -300.4\,kJ/mol$ (reactant); element in std state $\Delta G_f^\circ = 0$; $\Delta G_f^\circ = -370.4\,kJ/mol$ (pdt)

$\Delta G^\circ = \sum n \Delta G_f^\circ(\text{products}) - \sum m \Delta G_f^\circ(\text{reactants})$

$= 2\Delta G_f^\circ SO_3(g) - 2\Delta G_f^\circ SO_2(g)$

$= \left[2\,\text{mol} \times \frac{-370.4\,kJ}{\text{mol}}\right] - \left[2\,\text{mol} \times \frac{-300.4\,kJ}{\text{mol}}\right]$

$= [-740.8\,kJ] - [-600.8\,kJ]$ ("+")

$\Delta G^\circ = -140.0\,kJ$ (d)

5) Know $5Br_4(g) \rightarrow 5(g) + 2Br_2(l)$ Want ΔG°_{rxn} in kJ

$\Delta H^\circ_{rxn} = +115\,kJ$ $T = 25^\circ C \Rightarrow 298\,K$

$\Delta S^\circ_{rxn} = +125\,J/K$ ← need to convert

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$= (+115\,kJ) - (298\,K)\left(\frac{+125\,J}{K} \times \frac{1\,kJ}{1000\,J}\right)$

$= (+115\,kJ) - 37.2\,kJ$

$\Delta G^\circ_{rxn} = +77.8\,kJ$ (c)

6) Know $CCl_2F_2(\ell) \rightleftharpoons CCl_2F_2(g)$ Want ΔS for 1 mol in ↓

$\Delta H_{vap} = +17.2\ kJ/mol$

recall phase changes are @ equilibrium so $\Delta G = 0$

$T = 25°C \rightarrow 298\ K$

$\Delta G = \Delta H - T\Delta S$

$0 = \Delta H - T\Delta S$

$T\Delta S = \Delta H$

$\Delta S = \frac{\Delta H}{T} = \left(\frac{+17.2\ kJ}{mol} \times 1\ mol\right) \times \frac{1}{298\ K}$

$\Delta S = \frac{0.0577\ kJ}{K} \times \frac{1000\ J}{1\ kJ} = \boxed{\frac{57.7\ J}{K}}$ (a)

7) Know $Br_2(\ell) \rightleftharpoons Br_2(g)$ } boiling point Want T_b in °C

$\Delta H = 30.9\ kJ$

$\Delta S = 93.0\ J/K$

$\Delta G = 0$

$\Delta G = \Delta H - T\Delta S$

$0 = \Delta H - T\Delta S$

$T\Delta S = \Delta H$

$T_b = \frac{\Delta H}{\Delta S} = \left(30.9\ kJ\right)\left(\frac{K}{93.0\ J}\right)\left(\frac{1000\ J}{1\ kJ}\right)$

$T_b = 332\ K - 273 = 59.3°C \approx \boxed{59°C}$ (d)

8) Know $A + B \rightarrow C$

$\Delta H° = +30\ kJ$

$\Delta S° = +50\ J/K$

$\Delta G° = \Delta H° - T\Delta S°$

(+) (−) (+)(+)

↑ spontaneous if negative so temperature dependent in this case

$\Delta G° = 30\ kJ - T\left(\frac{50\ J}{K} \times \frac{1\ kJ}{1000\ J}\right)$

so if $0 = 30\ kJ - T(0.05\ kJ/K)$ ← closest to negative

$\frac{-30\ kJ}{-0.05\ kJ/K} = \frac{-T(0.05\ kJ/K)}{-(0.05\ kJ/K)}$

so $600\ K = T$ when zero so greater than 600 K will make it negative & spontaneous

(d)